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European Space Agency  
Research and Science Support Department  
Planetary Missions Division

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**ROSETTA-RPC-ICA**

To Planetary Science Archive Interface Control Document

RO-RPC-ICA-EAICD

Draft

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### Change Log

Date	Sections Changed	Reasons for Change
2016-09-07	Minor changes after review, plus a major update of 3.4.4.2 (CALIB directory)	Changes requested by reviewer
2016-10-27	New improved data quality flag system described (section 3.3) Added comments on interpreting browse plots, a follow up of the review process.	Changes requested by reviewer
2016-11-11	Update on software version 1 which is not used.	
2016-11-28	Updated table examples, mentioned that current version of data is version 2	Follow up to changes initiated by review process
2017-06-26	Revision of energy table, mainly affects section 2.4.1. Also removed some obsolete information on data processing and software.	ICA energy table determined with better accuracy.

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# 1 Introduction

## 1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is two fold. First it provides users of the Rosetta Plasma Consortium Ion Composition Analyzer (RPC-ICA) instrument with detailed description of the product and a description of how it was generated, including data sources and destinations. Secondly, it is the official interface between your instrument team and your archiving authority.

### 1.1.1 Contents

This document describes the data flow of the RPC-ICA instrument on Rosetta from the s/c until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained. Software that may be used to access the product is explained further on.

The design of the data set structure and the data product is given. Examples of these are given in the appendix.

## 1.2 Archiving Authorities

The Planetary Data System Standard is used as archiving standard by

- NASA for U.S. planetary missions, implemented by PDS
- ESA for European planetary missions, implemented by the Research and Scientific Support Department (RSSD) of ESA

### 1.2.1 ESA's Planetary Science Archive (PSA)

ESA implements an online science archive, the PSA,

- to support and ease data ingestion
- to offer additional services to the scientific user community and science operations teams as e.g.
  - search queries that allow searches across instruments, missions and scientific disciplines
  - several data delivery options as
    - direct download of data products, linked files and data sets
    - ftp download of data products, linked files and data sets

The PSA aims for online ingestion of logical archive volumes and will offer the creation of physical archive volumes on request.

## 1.3 Intended Readership

The staff of the archiving authority (Planetary Science Archive, ESA, RSSD, design team) and any potential user of the RPC-ICA data.





## 1.4 Applicable Documents

Planetary Data System Data Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part1

Planetary Data System Standards Reference, August 1, 2003, Version 3.6, JPL, D-7669, Part 2  
[Mission] Archive Generation, Validation and Transfer Plan, [month day, year], [doc number]

Rosetta Plasma Consortium Users' Manual, October 28, 2002, v. 0.994, RO-RPC-UM

Planetary Data System Data Preparation Workbook

Planetary Data System Standards Reference, August 1, 2003, Version 3.6

ROSETTA, Archive Generation, Validation and Transfer Plan, 06 October 2005, RO-EST-PL-5011

## 1.5 Relationships to Other Interfaces

This EAICD describes the overall RPC-ICA archiving details. If there will be changes in the archive format or labels this will affect both this document and the software which produces the PDS format data.

## 1.6 Acronyms and Abbreviations

PSA	Planetary Science Archive
ICA	Ion Composition Analyzer
IES	Ion and Electron Spectrometer, part of RPC instrument suite on Rosetta
PDS	Planetary Data System
RPC	Rosetta Plasma Consortium
MCP	Micro Channel Plate
IMA	Ion Mass Analyzer, twin instrument of ICA on Mars Express
CESR	Centre d'Etudes Spatiales et de Rayonnements
IRF	Institutet för rymdfysik (Swedish Institute of Space Physics)
FGM	Flux Gate Magnetometer
ES	Electrostatic in ES analyzer
TC	Telecommand
TM	Telemetry
GSE	Geo Solar Ecliptic coordinate system
UTC	Universal time
FOV	Field-of-view
HV	High Voltage
PROM	Programmable Read Only Memory
NRM	Normal instrument model
HAR	High Angular Resolution model



EXM Energy-mass matrix high mass resolution instrument model

## 1.7 Contact Names and Addresses

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## 2 Overview of Instrument Design, Data Handling Process and Product Generation

The Ion Composition Analyzer is an ion spectrometer designed to study ion dynamics with mass resolution. The design of the instrument is shown in figure 1.

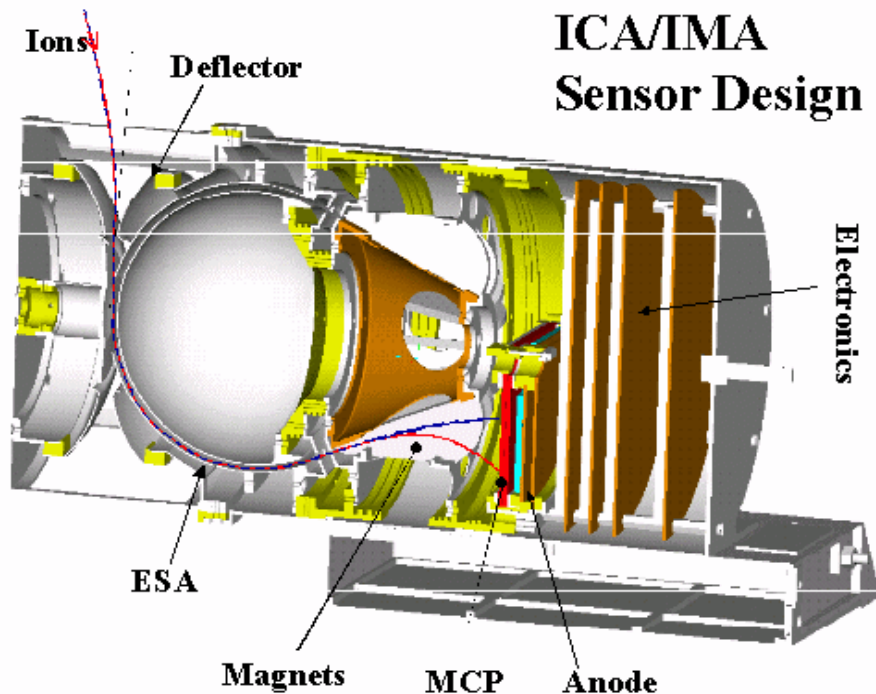


Figure 1 Overview of the ICA instrument



Particles enter the analyzer through an outer grounded grid. Behind the grid is a deflection system whose purpose is to deflect particles coming from angles between  $45^\circ$  and  $135^\circ$  with respect to the instrument symmetry axis (spacecraft y-axis) into the electrostatic analyser. This deflection system is named Deflector in figure 1 and the curved path of ions affected by the deflection electric field are shown as a red and a blue line. Ions within a swept energy pass band will pass the electrostatic analyzer (ES Analyzer, ESA in figure above). This is achieved by applying a high-voltage electric field between the inner and outer plate of the ES Analyzer. Only particles within the desired energy pass band will get just the right curvature of their path from this electric field so that they can pass the ES Analyzer. The geometrical (particle-optical) properties of the ES Analyzer determines the energy resolution which is 7% for ICA. The ions are then deflected in a cylindrical magnetic field set up by permanent magnets, labeled Magnets in figure 1. The field deflects lighter ions more than heavy ions. The blue line in figure 1 depicts the path of a heavy and energetic particle which deviates only a little from a straight path. Heavy particles will therefore hit close to the center of the detection area. The red line depicts the pass of an ion with lower mass and/or energy. The ions finally hit a micro-channel plate (MCP) which amplifies the signal from the particle so that it can be detected by charge sensitive amplifiers. The charges from the MCP are detected by an anode system with 16 anodes for detecting angle of arrival and 32 anodes to determine radial position and thus mass (radial position is affected by both mass and energy, but energy is known because of the ES Analyzer). The different angles of arrivals that can be detected are termed sectors, and the radial anodes are termed mass channels. Ions are analyzed in both direction and mass per charge simultaneously. The magnet assembly can be biased with respect to the electrostatic analyzer to post accelerate ions; this post acceleration enables a selection of both mass range and mass resolution. The energy range of the instrument is 25 eV/e to 40 keV/e, covered in 96 steps. The full mass matrix has 32 channels, which are grouped according to calibration data. Resolution and mass coverage will depend on ion energy and post acceleration setting. The spatial resolution of the instrument is  $22.5^\circ \times 4.5^\circ$ . The 16 anode sectors of the MCP constitutes a  $360^\circ$  field-of-view in the x-z plane of the spacecraft with  $22.5^\circ$  resolution. This angle will be referred to as the azimuthal angle of the instrument field-of-view. A field-of-view of  $51^\circ$  to  $131^\circ$  with respect to the spacecraft y-axis is in practice achieved through the deflection system, with an intrinsic angular resolution of the instrument of  $4.5^\circ$ . The electric field applied over the deflection plates bends the path of incoming particles so that those coming from some angle away from  $90^\circ$  with respect to spacecraft y-axis will be able to pass the electrostatic analyzer. This angle will be referred to as the elevation angle. The resolution in elevation angle is determined by the geometrical (particle-optical) properties of the instrument. The elevation angle resolution has been determined through calibration and the number of elevation steps has been tailored to provide an almost continuous coverage of the elevation field-of-view. The steps are nominally  $5.625^\circ$  apart to cover as close as possible the nominal angular range of  $\pm 45^\circ$  from the instrument measurement symmetry plane. Elevation angle index numbering is shown in figure 2, produced by A. Fedorov of CESR Toulouse. Figure 2 is the official reference to sector and elevation index numbering and will be included with the archived data in the GEOMETRY directory.

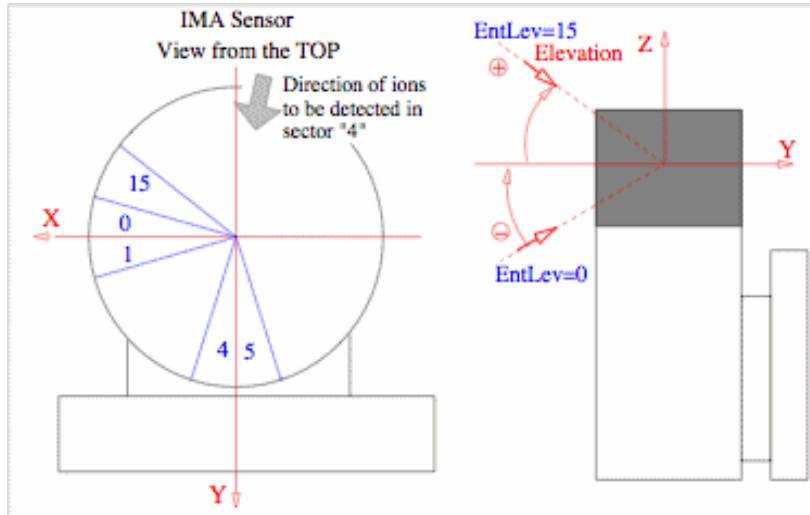


Figure 2 Sector and elevation angle numbering for ICA. Note that the sector numbering is for the physical location of the sector anode. The particles actually detected by that sectors comes from the opposite direction. This can be understood by studying the particle path described in figure 1. Note that the coordinates are in the instrument coordinate system used in the calibration report. Instrument Y is spacecraft -Z and instrument Z is spacecraft Y.

The spatial resolution transmitted to ground is dependent on available telemetry, as is the mass resolution. Therefore the data files from ICA contain a variable amount of mass channels, deflection angles and sectors. Which angles of arrivals (sector and elevation angle) and mass channels which have been added together must be known by the end user and this information must therefore be contained in the archive data. Data is further compressed using lossless compression, though the archived data will be uncompressed. One complete measurement cycle of all measured energies and 16 elevation angles always takes 192 s. for the standard 96 energy level mode.

The location of ICA on Rosetta is shown schematically in figure 3. The spacecraft coordinate system is shown so that sector and elevation angles (through figure 2) can be related to the spacecraft coordinate system.

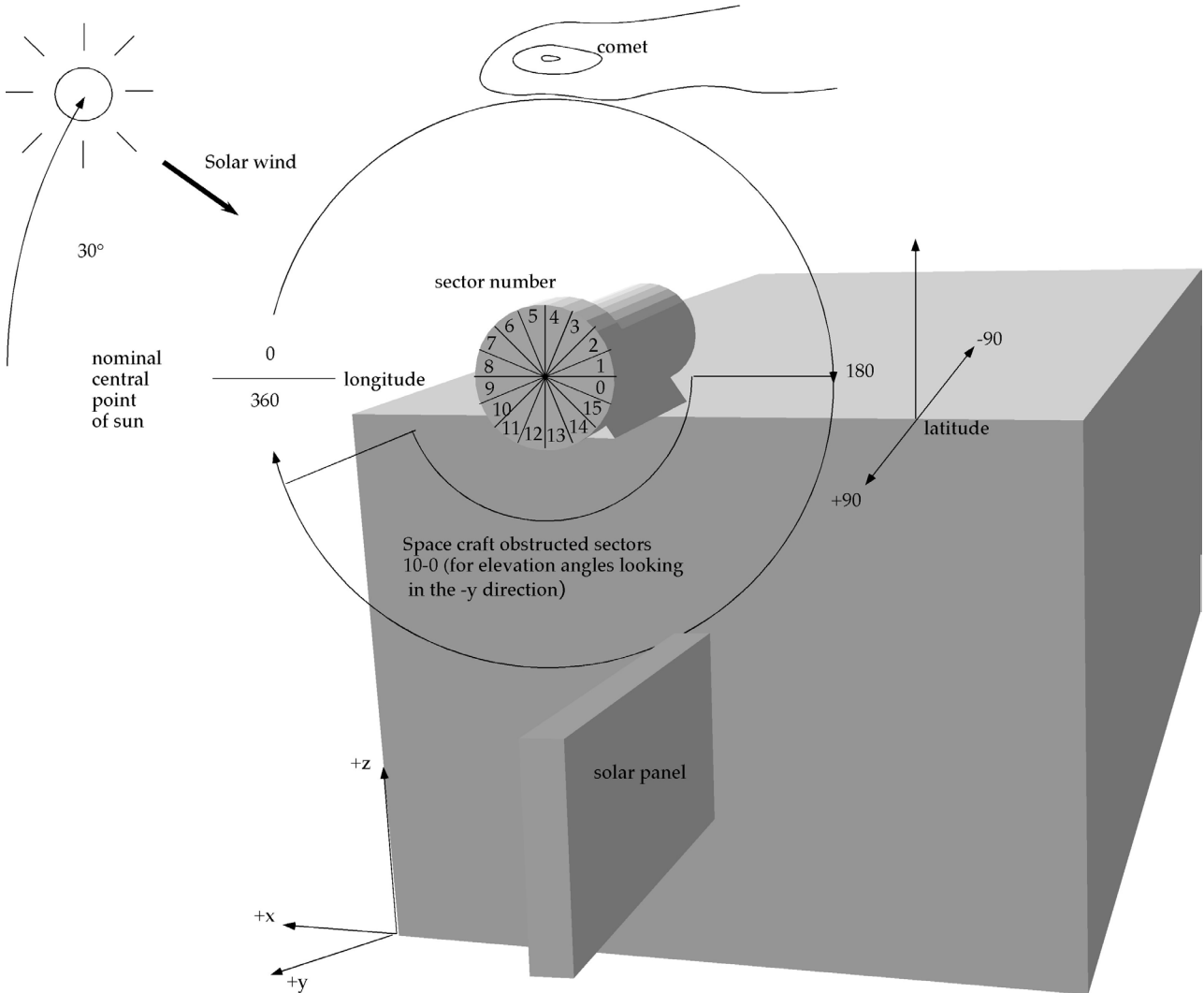
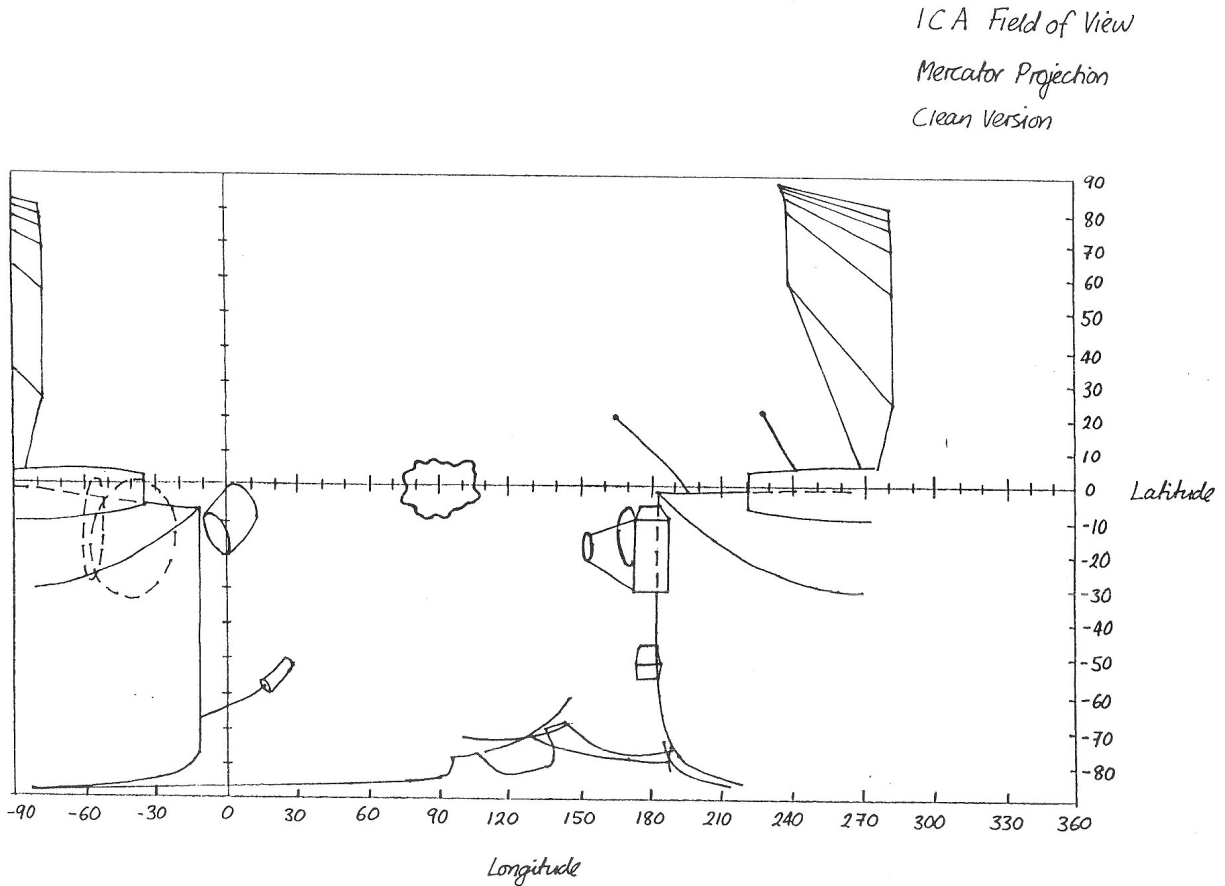


Figure 3 Location of ICA on the spacecraft. Also shown are the sectors (10 - 15 and 0) which for some elevation angles (index 0-7) are shadowed by the spacecraft. The latitude and longitude scales are used in figure 4.

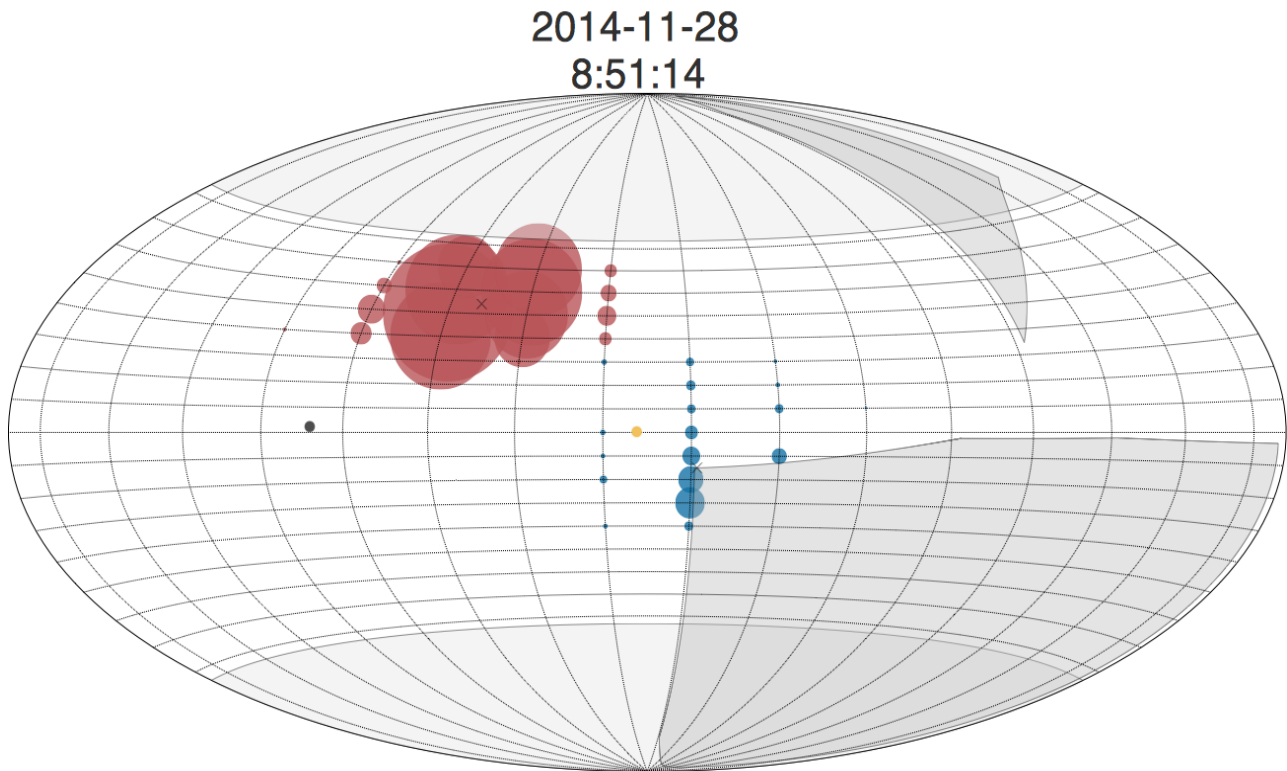


The field-of-view of the ICA can also be shown using the latitude and longitude definitions shown in figure 3, which is done in figure 4.



**Figure 4 Rosetta seen from the ICA point-of-view. Latitude and longitude defined in figure 3. Note that this handwritten figure is not exact, it is intended as an indication where the spacecraft and solar panels are within the ICA field-of-view. The spot at 90° longitude, 0° latitude is the nominal position of the comet.**

Note that -90 and 270 degrees in figure 4 are the same. In nominal comet-pointing position the comet will be at 90° longitude, 0° latitude. The approximate angles which can be affected by the solar panels can be seen. The region between -10° and 180° is the free field-of-view of ICA. Longitudes below -10° and above 180° are totally blocked by the spacecraft for negative latitude. Figure 3 and 4 will be stored in the GEOMETRY directory of the archive.



*Figure 5 ICA field-of-view with a simplified spacecraft model showing the spacecraft obstruction (medium gray) and regions outside the ICA field of view (light gray). Sample data are shown with red (protons) and blue (water ions) circles.*

Figure 5 shows another version of the ICA field of view, with also some sample data. Red circular patches indicate protons, blue water ions. The sizes of the patches indicate the flux coming from that particular direction. Due to the limited field of view, such plots are helpful to judge how much of the observed populations are within the instrument field-of-view.

ICA data is delivered as a time series of energy spectrograms. If the data is plotted as such a time series, the elevation sweep will be seen in the time series. A narrow angle signal, such as an undisturbed solar wind, will then be seen as a pattern repeating every 16 time steps (elevation steps).

Similarly a repeating pattern may be found when ICA is used in alternating post-acceleration mode. Then one setting is used for one set of 16 different elevation steps, then another value for the next 16 elevation steps. For low post acceleration the instrument may lose much of the proton signal, which may then appear modulated.

Finally, when separating the raw data into masses, one must consider that there may be some cross talk between the physical mass channels. A strong proton signal will usually leak to all mass channels. This can usually be quite easily identified if the data is summed over the time period of interest and plotted as function of energy and mass channel.



## 2.1 Scientific Objectives

ICA supports the RPC science goals by measurements of three-dimensional ion velocity distributions with mass resolution and derived quantities such as density, flow velocity and temperature for different ion species. Because Rosetta is not a spinning spacecraft ICA cannot achieve full angular coverage. This will limit the ability to derive 3D moments and probably make it unfeasible to automatically generate moments for the database. Cometary origin ions will often form beam distributions which when within the instrument field-of-view can be well characterized. Other common distributions will be torii and shell distributions in which case a fitting procedure can be used on a case basis, this is also true for hot enough populations when the measured part of velocity space represents a significant part of the total particle population. The most important aspect of ICA is the mass resolution which distinguishes it from the Ion Electron Spectrometer (IES) of the Rosetta Plasma Consortium (RPC). The cometary origin ions are to a large extent  $O^+$  and water group ions. These are significantly heavier than the major solar wind ions ( $H^+$  and  $He^{++}$ ). Thus the important pick-up of heavy cometary origin ions by the solar wind, and subsequent deceleration of the solar wind can be studied. As soon as the comet gets active enough to release significant amounts of ionized gas to the solar wind ICA will be able to detect increased counts of heavier ions. The gradual increase of the cometary activity, as well as fine structure related to structure in the outflow from the comet can be studied (i.e. surface jets). Boundaries between the solar wind and the cometary ionosphere can be studied, including transient plasma transfer phenomena

## 2.2 Data Handling Process

Data is unpacked into raw data files at IRF in Kiruna. After that data, housekeeping and geometry data are transferred directly to PDS format ASCII tables for raw data and transferred to the RPC server at Imperial College. Data is transferred to the PSA from Imperial College.

Background subtraction, which must be performed case-to-case, can be made by the users themselves, and calibration tables applied after that. Browse graphics file of all – direction averaged spectra are produced for two mass-bins (high and low) and delivered to the PSA.

A possible strategy to automatically remove the background has been tried for Mars Express IMA data and can be used by the end user on high resolution ICA data. One uses the fact that for significant counts of a real signal, one will always get signal from several contiguous mass channels. Usually the signal will also be seen in several adjacent energy channels. Therefore one can remove all occurrences of counts in a single mass and energy channel, where there are no counts in neighboring channels. This gives a much lower background around significant real peaks in the data. It does lower the sensitivity of the instrument. For weak signals one needs to first integrate for several full measurement periods. In such a case the noise will also add up and may show up as larger groups of several adjacent mass and energy channels with non-zero counts.

## 2.3 Product Generation and Data Validation

The raw data products are generated upon unpacking of the telemetry data. Certain information not contained in the telemetry must be added, such as currently valid calibration files. This is straightforward and can be done as the data arrive. Calibrated data requires more, possibly manual work, and will be delivered later than the raw data.

Sometimes unpacking fails due to data corruption. Such data is currently not delivered to PSA.

All data is unpacked and processed at IRF. Further transmission to the ESA archive takes place according to the delivery plan agreed upon between the experiment teams and ESA.





## 2.4 Overview of Data Products

The ICA data products consists of the raw counts produced by the in-flight data (section 2.4.4, which are interpreted and turned into calibrated data using tables containing the calibration results (section 2.4.3). Derived products (moments), section 2.4.7, are not expected to be delivered as these require manual inspection and choices which must be done on a case by case basis. There are no pre-flight data products nor any sub-system tests.

The ICA team has delivered updated versions of the L2 data, the up to date version is version 2. The energy tables have also been updated, most recently with data delivered after 2017-06-26.

### 2.4.1 Instrument Calibrations

Calibration tables from the calibration of the flight model will be stored. These include energy tables, deflection angle tables, mass channel to ion mass tables for different post-acceleration levels, and counts to flux conversion tables for a given post-acceleration and MCP bias. Different energy and elevation tables are used. The table used is given in the label for the data. The tables used are given by the onboard software version. Because of in situ calibration efforts, these energy tables have in turn been adjusted so that they exist in different versions. Only one version, the latest one at the time of delivery, is included in the archive. The calibration tables are given in PDS format with detached labels. These are for the energy resolution:

ICA\_ENERGY\_TABLEN\_VNN.TAB and ICA\_ENERGY\_TABLEN\_VNN.LBL where NN is the version of the onboard software

which contains 96 rows with 2 columns. The columns are

Index number of the energy level (i.e. just a counter which corresponds to the data points in the PDS data file), and energy per charge [eV] of detected ion. The indicated energy is the center energy for this energy band. The beginning of table ICA\_ENERGY\_TABLE\_V04.TAB is shown below.

0,	-1.0
1,	-1.0
2,	2.5
3,	7.8
4,	13.1
5,	18.4
6,	23.7
7,	29.0

Low energies come first. This does not reflect the actual measurement sequence, the analyzer voltage is stepped from high to low. It is however much more convenient for the end user to have the energy go from low to high. The fill value -1.0 corresponds to non valid energy steps, positively charged ions cannot get through the electrostatic analyzer for this setting of the voltages. However, when the instrument is cold there can be a significant offset of the zero-level of the high voltage, and for such cases there can be a significant signal for these energy steps. The best possible temperature drift correction is the subject of the ongoing ESA funded enhanced archive effort. In the L2 data, a quality flag is set when the temperature of the



instrument is low enough that drift of the energy scale may occur, see section 3.3.

For the entrance deflection the table is

ICA\_ELEVATION\_TABLE\_VNN.TAB and ICA\_ELEVATION\_TABLE\_VNN.LBL where NN is the version of the onboard software.

ICA can be booted using different versions of the onboard software. Different versions of the software will use different energy, mass lookup and elevation tables. There is therefore one version of each table for each software version. The software version in turn is determined through the PROM section, which is given in the data. The relation between PROM section and software version is given in the table at the end of this paragraph. The end user need not determine the appropriate table through this table, it is given in the label file.

The elevation table contains 16 +1 columns and 96 rows, where 16 corresponds to the amount of elevation angles and 96 to the amount of energy levels. The energy index number is given in the first column. A sample close to nominal value obtained at intermediate energy index 42 is shown below:

38.6,-33.2,-28.0,-22.6,-17.4,-12.2, -7.1, -1.7, 3.8, 8.9, 14.2, 19.6, 24.8, 30.1, 35.3, 40.6

At low (below 300 eV) and high (above 15 keV) energy the angular resolution and coverage deviates significantly from nominal values. At low energy this is because of insufficient resolution of the digital to analog conversion. At high energies the discrepancy is due to insufficient high voltage to deviate the flight path of the more energetic ions. This table can be used by the end user to get accurate conversion of elevation index into actual physical angle from the spacecraft X-Z plane. Otherwise nominal values can be used (for approximate visualization purposes) with the angle given by:

$-42.1875 + \text{elev} * 90 / 16$  where elev is the elevation index number (0-15)

The angle within the X-Z plane, from X towards Z, is given by the sector (or azimuth angle index).as

$-168.75 + \text{azim} * 360 / 16$  where azim is the azimuth index (0-15, same as sector number).

The ICA has a command, enable bad-HV masking. This sets all deflection angle and energy combinations which deviates substantially from nominal values to zero. However, experiences from Mars Express shows clearly that it is better to set the elevation angle setting to zero for the low energy case and keep the data. Therefore a new table with deflection angle as close to zero as possible is now used for energies below 100 eV where the limited elevation angle accuracy problem may occur. However, the command for bad-HV masking exists and may be used again in the future. For high energies the deflection voltage is set to as high as possible and this data will not be masked either, but will not have the deflection angle nominally specified. Therefore the end-user must have access to this table

Finally, mass look-up and mass calibration tables must be used. The mass look-up tables are used on-board to reduce the telemetry. As described in section 2 ICA has 32 mass channels. Ions of a certain mass will hit the detector surface (MCP) at some range of mass channels, and this range will vary with the energy. Therefore the mass look-up table must have one entry for each energy, telling what range of mass channels to put together. Furthermore the post-acceleration setting will also affect where the particles hit the detector surface. Therefore ICA has three mass look-up tables for three different post-acceleration settings (labeled 0, 1 and 2 in the calibration document). For high mass-resolution modes the actual mass-channel data will be transferred to ground, possibly binned (32, 16 or 8 bins). For lower resolution than that the data is instead



binned into mass-groups according to the mass look-up tables. These tables are named ICA\_MASS\_LOOKUP\_TABLEN\_VNN.LBL and ICA\_MASS\_LOOKUP\_TABLEN\_VNN.TAB

Where N is 1,2 or 3 depending on the post-acceleration setting. Note that the actual post-acceleration setting is from 0-2 according to the calibration document, but later mass look-up table 0 will be used to specify that no mass look-up table was used. The file contains 12+2 column elements and 96 rows. Each row contains post-acceleration level it is valid for, the energy index and 6 different ion mass ranges (2 values, start and stop), nominally corresponding to H+, >O+, O+, He+, He++, O++. In practice this is not the actual mass range at low energy for all data, due to a discrepancy in the onboard table. The end user should therefore carefully check the mass channel ranges binned together.

The column elements specifying mass range are given as start mass channel, end mass channel. A value of -1 indicates that the indicated ion mass range cannot be seen by the instrument for that particular energy and post-acceleration setting.

A sample line for energy index 42 and no post-acceleration:

0,42, -1, -1, 0, 14, 15, 20, 27, 31, -1, -1, 21, 26

Meaning that for no post-acceleration (0) and energy level 42, H+ cannot be measured (-1), >O+ ions are found between mass channels 0 to 14, O+ between 15 to 20, He+ between 27-31, He++ cannot be measured and O++ is found between mass channels 21 and 26. The reason for the strange order is that for severe telemetry restrictions not all mass bins are transmitted, and then Larger than O+ (a large group of everything above O+), O+ and H+ are the most important to transmit.

The reason for the larger than O+ mass group (>O+) is that if only two mass ranges are allowed due to telemetry constraints, then H+ (solar wind) and heavy cometary ions can be distinguished.

For mass lookup tables, the post acceleration table index is related to the setting (0-7) as follows:

TABLE	SETTING
1	0
2	1-4
3	5-7

PDF graphics files defining the geometry of measurements are included in the GEOMETRY directory. One is the SECTORS.PDF shown in figure 2. Another one is the ICA field-of-view (ICALOCATION.JPG and ICA\_FOV.JPG), also shown as figure 3 and 4 in this document.

ICA uses a number of different energy and elevation tables. They are summarized below. Version 1.0 is the originally delivered table which has never been used in practice. Version 2.0 was loaded into all EEPROM banks before use of ICA. Later new patches were loaded into the eeprom banks, going from the highest number towards the lowest.

Version	loaded in PROM bank	Origin	Comment
2.x	all, except as below	Andrei's original table	v2.1 interprets this with ESC_H=33.33V



Version	loaded in PROM bank	Origin	Comment
3.x	15	Hans' Earth flyby table	v3.1 interprets this with ESC_H=33.33V
4.x	14	Martin's recalculated table originally assuming 34.5V offset on ESC_H	v4.1 interprets this with ESC_H=33.33V
5.x	13	Martin's recalculated table originally assuming 32.5V offset on ESC_H	v5.1 interprets this with ESC_H=33.33V
6.x	12	Martin's recalculated table originally assuming 30.5V offset on ESC_H	v6.1 interprets this with ESC_H=33.33V
7.x	11	Low energy table with 33.33V ESC_H, new mass bin tables, fix elevation	
8.x	10	Fast low energy table with 33.33V ESC_H, new mass bin tables, fix elevation	
9.x	9	Same as 4.x but with correct mass bin tables	v9.0 interprets this with ESC_H=33.33V
7.x	8	Same as bank 11: Low energy table with 33.33V ESC_H, new mass bin tables, fix elevation (after 2015-04-28)	
10.x	7	Same as bank 9 but with but with link packet delay doubled (internally named version 10)	v10.0 interprets this with ESC_H=33.33V

Note that only the latest interpretation is delivered to the archive. All tables for version 10 are identical to the ones for version 9, the only difference is a change to the link packet delay. To make the data consistent, we still deliver separate tables for software version 10.

### 2.4.2 In-Flight Data Products

The ICA instrument gives essentially only one raw data (Level 2) output, counts. The instrument obtains counts for each energy level, sector, elevation angle and mass channel (as described in section 2). One full distribution is obtained in 192 s for all modes except the solar wind mode which takes 64 s. The instrument makes measurements in the same way regardless of available telemetry rates. To reduce the data rate, the data is reduced in resolution. Elevation angles, sectors and mass channels are added together into larger bins. Data is never binned over energy and time in this way. In May 2015 two new modes were introduced, with no elevation scanning and only low energy coverage, but with a time resolution of 1s and 4s. The mode used can be determined from the PROM section used.

The raw data is thus in principle 4-dimensional, but must be stored as a two-dimensional table. The size of the sector, elevation angle and mass channel bins will vary continuously depending on available telemetry and loss-less compression ratio. It is thus not feasible to vary the tables after the current angular and mass resolution. Therefore start and stop values for each bin (sector, deflection angle and mass) must be included in the data. Start and stop values for elevation angle, sector and mass bins add 6 fields to the table. For the mass bins an on-board table-look up which is energy dependent may have been used onboard. Therefore one field is used to describe which table was used (and a keyword in the label gives which revision of the table), where table 0 indicate that no mass-lookup table was used.





ICATables.pdf by A. Fedorov

All stored in Portable Document Format (pdf) in the DOCUMENTS directory.

#### **2.4.5 *Derived and other Data Products***

The L3 (calibrated) data can be used to calculate higher order data (moments), but as the ICA field-of-view is not complete the feasibility of such calculations must be individually judged for each event, and this is thus not foreseen to be included in the PSA. Furthermore one must for each event judge if the moments should be fitted functions (Maxwellians) to take into account truncation due to the limited field-of-view or a numerical integration (which is used when the entire particle population is within the field-of-view of the instrument).

#### **2.4.6 *Ancillary Data Usage***

Spacecraft attitude and orbit data are necessary. In particular, it is necessary to transform between the spacecraft coordinate system and some common system such as GSE and any mission specific comet centered coordinate system. The RPC fluxgate magnetometer (FGM) data is necessary to transform into magnetic coordinates. A common definition must be made for all of RPC but pitch-angle (angle between magnetic field and viewing direction) must at least be calculated. The plane perpendicular to the magnetic field may be described by another angle with zero towards the sun or towards the comet.

### **3 Archive Format and Content**

#### **3.1 Format and Conventions**

##### **3.1.1 *Deliveries and Archive Volume Format***

PDS compliant data will be delivered to ESA at DATA SET Level. One data set corresponds to one volume. Data of different processing levels will be archived in different data sets.



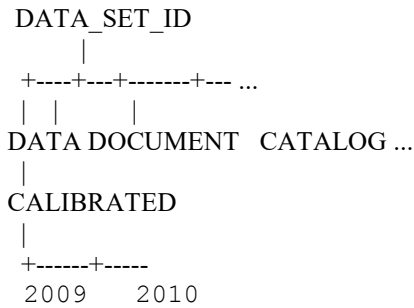
### 3.1.2 Data Set ID Formation

RO-E/M/A/C-RPCICA-x-phase-description-Vn.m

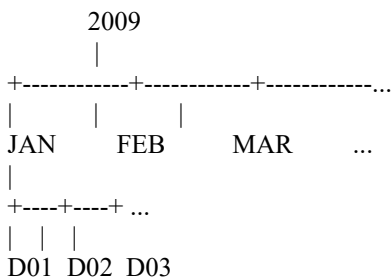
- E/M/A/C = Earth/Mars/Asteroid/Comet
- RO = INSTRUMENT\_HOST\_ID
- RPCICA = INSTRUMENT\_ID
- x = {2,3} Codmac Data processing level numbers.
- description = {RAW, CAL}
- phase = {...,ESC1,...}
- Vn.m = Version number

Within each data set TARGET\_NAME and TARGET\_TYPE will then be used to identify the current target. (Thus they will not stay the same within one data set, but data set id will.)

### 3.1.3 Directory Naming Convention



The top level directory of the data set is named by DATA\_SET\_ID according to PDS specifications. This is found under a top level RPC directory structure as shown above at the Imperial College server. Under DATA a directory specifying the type of data (EDITED, CALIBRATED) is used, but this is in practice redundant as a new DATA\_SET must be used for each type of data. The DATA is further subdivided as:





### 3.1.4 File naming Convention

ICA will produce three types of science data files for uncalibrated data and three types for calibrated data. These are data for 96, 32 and 8 energy step modes. Furthermore an edited housekeeping data file and geometry data file will be produced.

POSITION: 012345678901234567890123.012  
FILENAME: RPCICAYMMDDTHH\_XXX\_nnLL.EXT

YY = Year

MM = Month

DD = Day

T = Time separator

HH=hour

xxx = file running number to allow for several files in one time period

nn = 08, 32 or 96 depending on energy step mode. Not used for HK and GEOM files

LL = L2 for raw counts, L3 for calibrated data, HK for housekeeping and GEOM for geometry

EXT = LBL or TAB

## 3.2 Standards Used in Data Product Generation

### 3.2.1 PDS Standards

ICA complies to PDS version 3, and we use version 3.6 of the PDS standard reference.

### 3.2.2 Time Standards

All references to time in the ICA PDS archive will be to UTC. Then time is displayed using the PDS standard CCYY-MM-DDThh:mm:ss.sss we will convert space craft time into UTC in this format (not GMT as the original PDS definition). The conversion will be done from the epoch 2000.

Housekeeping files will also contain the spacecraft clock time (i.e. unconverted and uncorrected ticks.)

The spacecraft Clock (OBT) is given in the label files as "1/nnnnnnnnnn.nnnnn"

It is the SPACECRAFT\_CLOCK\_START/STOP COUNT which is given as OBT. The OBT is described in **Rosetta Time Handling, RO-EST-TN-3165, sect. 4.2.**

The general principle is as follows:

SPACECRAFT\_CLOCK\_START/STOP\_COUNT = "<reset number>/<unit seconds>.<fractional seconds>"

Where the unit seconds and the fractional seconds are separated by the full stop character ("."). Note that this is not a decimal point. The fractional seconds are expressed as multiples of  $2^{(-16)} = 1.53E-5$  seconds and count from 0 to  $2^{16} - 1 = 65535$ .

E.g. in SPACECRAFT\_CLOCK\_START\_COUNT = "1/21983325.392" the 392 fractional seconds correspond to  $392 * 2^{(-16)} = 0.00598$  decimal seconds.

The spacecraft clock could be reset during the mission (although this is not planned). This would imply a change of the zero point. The zero point of the OBT will be indicated by pre-pending the reset number (integer starting at 1) and a slash to the unit seconds, i.e. "1/" means OBT = 0 at 2003-01-01T00:00:00





UTC.

### 3.2.3 Reference Systems

Reference systems used in this document and the ICA PDS data:

Reference system	Description
Instrument coordinates	THE ICA instrument coordinate system. Retained for consistency with calibration report. Aligned with spacecraft Cartesian coordinate system, but different definition of the axes.
Spacecraft coordinate system	Orientation: x: pointing from the LANDER to the s/c center, perpendicular to solar array axes; y :parallel to solar array axis; pointing to the left, when standing in front of the Lander, z: pointing up

### 3.2.4 Other Applicable Standards

N/A

## 3.3 Data Validation

Data will be scanned for internal consistency when decommutating to edited raw format. Derived data will when possible be compared to independent measurements by other instruments. The solar wind is particularly useful as it is a narrow beam which, when at all within the field-of-view, is typically fully measured by ICA. When changes are made to one of the RPC ion spectrometers (ICA and IES), such as changing the MCP bias, this can be made when both instruments have the sun (solar wind) in the field-of-view. That way the relative change of the sensitivity can be estimated.

Before archiving a data set from some mission phase, this set will have been used internally by RPC scientists. It is planned to base all scientific analysis on the data products formatted. To actually have the data used by scientists before delivery to archive is considered the best way of revealing problems, and this is the approach taken by RPC.

In the label a QUALITY\_ID keyword is used to indicate the quality of the data. As this is raw data, we provide an indicator of possible problems, using two digits, one for instrument temperature and one for instrument background levels. No known problems are identified with 00.

Low instrument temperature leads to a drift of the low energy channels of the instrument. Below about 13 °C this may happen. The effect is pronounced and a clear problem below about 0 °C. We therefore set the temperature flag to 1 if more than 5 temperatures readings in an hour are below 13 °C, and to 2 for at least 5 temperature readings below 0 °C. The number 5 is arbitrary, but a number larger than 1 reduces the influence of noise and erroneous temperature readings which may occur just after startup.

Similarly, low instrument temperatures may lead to enhanced noise, as can lack of on board background subtraction and sometimes EUV light can enter the instrument. Therefore the highest energy channels are used to monitor the noise level as it is in the delivered raw data. The noise flag has, like the instrument flag, 3 levels, where 0 means no known problem, 1 is elevated levels and 2 means significantly elevated levels. The averaged background level over the 1 hour interval is used.



Data with non-zero quality flag can mostly be used, in particular data from the main mission. However for data with temperature flag set to 2, the indicated energy of low energy particles can be significantly off. For the noise level, the user can in most cases perform a noise reduction for data with increased background levels.

### 3.4 Content

#### 3.4.1 Volume Set

The one data set on one volume basic volume organization is used. Thus the volume directory structure looks like the following:

ROOT

- |-- AAREADME.TXT
- |-- ERRATA.TXT
- |-- VOLDESC.TXT
- |

-----

CALIBRATION CATALOG	SOFTWARE	CALIB	GEOMETRY	INDEX	DATA

#### 3.4.2 Data Set

Our naming convention for the data set will follow the same principles as the DATA\_SET\_ID thus.

DATA\_SET\_NAME="ROSETTA-ORBITER E/M/A/C RPCICA 2 DDDDDDD V1.0"

- ROSETTA-ORBITER = INSTRUMENT\_HOST\_NAME
- E/M/A/C = EARTH MARS ASTEROID COMET
- RPC-ION-MASS-ANALYZER = INSTRUMENT\_NAME
- 2 = Data processing level numbers
- DDDDDDDDDDDDDD = Data set will include Edited data or Calibrated data
- DDDDDDDDDDDDDD = Processing level in text, i.e. EDITED or CALIBRATED

One data set will be used for each processing level. Multiple targets will be used for each data set and within each data set TARGET\_NAME and TARGET\_TYPE will be used to identify the current target (Thus they will not stay the same within one data set, but data set id will). The data set name fits in the full length thus 60 characters.



### 3.4.3 Directories

#### 3.4.3.1 Root Directory

*Table 1: Root Directory Contents*

<b>File Name</b>	<b>File Contents</b>
VOLDESC.CAT	A description of the contents of this Volume in a PDS format readable by both humans and computers
CALIB/	Calibration directory
CATALOG/	Catalogue directory
DOCUMENT/	Document directory
INDEX/	Index directory
DATA/	Data directory
BROWSE/	Browse directory
GEOMETRY/	Geometry directory
LABEL/	Label directory
SOFTWARE/	Software directory



### 3.4.3.2 Calibration Directory

ICA can use a number of different onboard energy, elevation and mass lookup tables. Which onboard software version was used is given by the version number, V01 in the samples below. The corresponding calibration tables found in the CALIB are named after the different ICA software versions actually used. Note that software version 1 was never used in practice, it was stored in the ROM onboard, not the EEPROM which was always used in flight. The label file for the data contains information about which tables were used by providing the name of the correct file. The ICA software version can also be obtained from the PROM section and the date of the data according to the below table:

ICA software Version	loaded in PROM bank	Origin
2.x	all, except as below	Original table
3.x	15	Earth flyby table
4.x	14	recalculated table originally assuming 34.5V offset on ESC_H
5.x	13	recalculated table originally assuming 32.5V offset on ESC_H
6.x	12	recalculated table originally assuming 30.5V offset on ESC_H
7.x	11	Low energy table with 33.33V ESC_H, new mass bin tables, fix elevation
8.x	10	Fast low energy table with 33.33V ESC_H, new mass bin tables, fix elevation
9.x	9	Same as 4.x but with correct mass bin tables
7.x	8	Same as bank 11: Low energy table with 33.33V ESC_H, new mass bin tables, fix elevation (after 2015-04-28)
10.x	7	Same as bank 9, but with different link packet delay time

Table 1: Calibration Directory Contents

File Name	File Contents
CATINFO.TXT	A description of the contents of this directory
ICA_ELEVATION_TABLE_V02.LBL, .TAB	Calibration table describing the elevation angle corresponding to each elevation index, as a function of particle energy. The angle given is the center angle.



*Table 1: Calibration Directory Contents*

ICA_ENERGY_TABLE_V02.LBL, .TAB	Calibration table describing the particle energy corresponding to each energy index level. The energy indicated is the center energy of the bin.
ICA_MASS_LOOKUP_TABLEN_V02.LBL, .TAB	Calibration tables describing the mass channels corresponding to 6 different ion mass intervals as a function of energy. <i>N</i> is 1,2 or 3 where table 1 is used in the case of no post-acceleration, table 2 when post-acceleration reference level is 1-4 and table3 when post-acceleration level is 5-7.

### 3.4.3.3 Catalog Directory

*Table 3: Catalog Directory Contents*

File Name	File Contents
CATINFO.TXT	A description of the contents of this directory
UNCALIBRATED_DS.CAT	PDS Data Set catalog description of all the ICA un-calibrated level 2 data files
CALIBRATED_DS.CAT	PDS Data Set catalog description of all the ICA calibrated level 3 data files
DERIVED_DS.CAT	PDS Data Set catalog description of all the ICA derived level 5 data files, if this will exist
INSTHOST.CAT	PDS instrument host (spacecraft) catalog description of the Rosetta orbiter spacecraft
INST.CAT	PDS instrument catalog description of the ICA instrument
MISSION.CAT	PDS mission catalog description of the Rosetta mission
PERSON.CAT	PDS personnel catalog description of ICA Team members and other persons involved with generation of ICA Data Products
REF.CAT	ICA-related references mentioned in other *.CAT files
SOFTWARE.CAT	PDS software catalog description of ICA software



### 3.4.3.4 Index Directory

Table 4: Index Directory Contents

File Name	File Contents
INDXINFO.TXT	Dataset Index File
BROWSE_INDEX.LBL BROWSE_INDEX.TAB	Browse index file
INDEX.LBL INDEX.TAB	Data index file
	No other index files will be used

### 3.4.3.5 Browse Directory and Browse Files

Contains png files of all-direction raw spectrograms binned into two mass bins (low and high) for a fixed time interval of 1 hour. The data is organized in the same structure as the data, i.e. year, month and day are directories which contain png and corresponding label (.LBL) files. . Description in BROWSEINFO.TXT.

Table 5: Browse Directory Contents

File Name	File Contents
BROWSEINFO.TXT	Information about the Browse data
DATA	Contains .LBL and :TAB files with the plot data as ASCII files
YEAR	Directories containing browse plots from each year. See directory structure below.

The YEAR catalogue structure follows that of the archive format, i.e. in the BROWSE directory a structure with the following principal format can be found:

```

BROWSE
|
|--BROWINFO.TXT
|--BROWSE.HTM
|--BROWSE.LBL
|
DATA
|
+-----+-----...
|       |

```



```

2005 2006 ...
  |
  +----+----...
  |    |
MAY  OCT ...
  |
  +----...
  |
D01 ...
  |
PNG picture files
  
```

### 3.4.3.6 Geometry Directory

Files of the instrument viewing geometry, taken from the calibration documentation, will be provided. Figures 2,3 and 4 of this document will be included as SECTORS.PDF shown in figure 2, ICALOCATION.JPG (figure 3) and ICA\_FOV.JPG (figure 4).

*Table 6: Geometry Directory Contents*

File Name	File Contents
ICALOCATION.JPG	A figure describing where ICA is located on Rosetta, as well as relating the ICA instrument and spacecraft coordinate systems to each other.
SECTORS.PDF	Figure describing the sector (azimuth) and elevation index numbering in the instrument coordinate system.
ICA_FOV.JPG	Rosetta seen from the ICA field-of-view in a local latitude-longitude coordinate system explained in figure ICALOCATION.JPG

### 3.4.3.7 Software Directory

Sample MATLAB files to read ICA ASCII archive files are provided, as well as a commented sample on how to produce a spectrogram plot. The files are named READICA2.M and PLOT\_ICA.M.

*Table 7: SOFTWARE Directory Contents*

File Name	File Contents
READICA2.M	File to read ICA data into the MATLAB workspace. Asks for a date and read all data for that date
PLOT_ICA.M	Sample program to plot ICA data. Mainly to illustrate how one can work with the raw data.
ICAINITIALIZE.M	Script to initialize the workspace by for example reading the ICA energy table into the workspace. Needed to run PLOT_ICA.M
IMPORT_L2.M	Support function to READICA2.M. Reads one data file
GET_SW_VERSION.M	Support function to PLOT_ICA.M. Translate prom number & date to software version



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### 3.4.3.8 Label Directory

This directory is not used.





## 3.4.3.9 Document Directory

<i>Table 8: Document Directory Contents</i>	
<b>File Name</b>	<b>File Contents</b>
DOCINFO.TXT	A description of the contents of this directory and all subdirectories.
ICA_EAICD/	Directory containing the ICA EAICD document
ICA_EAICD/ICA_EAICD.HTM	The ICA Experiment-Archive Interface Control Document as hypertext
ICA_EAICD/ICA_EAICD.ASC	The ICA Experiment-Archive Interface Control Document in ASCII text
ICA_EAICD/ICA_EAICD.PDF	The ICA Experiment-Archive Interface Control Document in PDF format
ICA_EAICD/ICA_EAICD.DOC	The ICA Experiment-Archive Interface Control Document in MSWordXP format
ICA_EAICD/ICA_EAICD.LBL	A PDS detached label that describes ICA_EAICD.HTM, ICA_EAICD.ASC, ICA_EAICD.PDF and ICA_EAICD.DOC
ICA_INST/	Directory containing the ICA instrument paper
ICA_INST/*	Similar to ICA_EAICD/*
ICA_CALIB/	Directory containing information regarding calibration
ICA_CALIB/*	Similar to ICA_EAICD/*
ICMA_TCTM.PDF	“The ICA-IMA TC/TM data formats and related software aspects” by Hans Borg
ICA_CMD_BRIEF.PDF	“ICA Command Description” by Hans Borg
ICA_CAL.PDF	“ICA calibration report” by Andrei Fedorov
ICATABLES.PDF	ICA Tables by A. Fedorov
Other Documents	Additional documents describing data processing, etc.
Other Document labels	Detached PDS labels for any additional documents

## 3.4.3.10 Data Directory

<i>Table 9: Data Directory Contents</i>	
<b>File Name</b>	<b>File Contents</b>
CATINFO.TXT	A description of the contents of this directory
RPCICAYMMDDTHH_000_96L2.LBL, .TAB	Label and table files containing ICA data
RPCICAYMMDDTHH_000_GEOM.LBL, .TAB	Label and table files with geometry data
RPCICAYMMDDTHH_000_HK.LBL, .TAB	Label and table files with housekeeping data

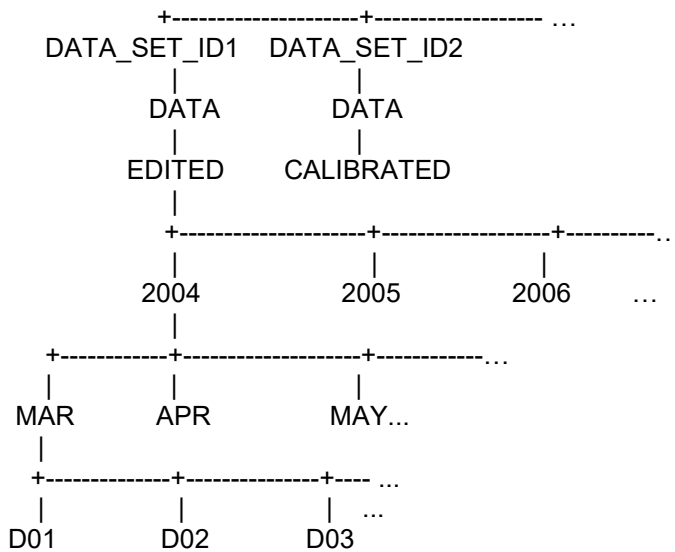


## 4 Detailed Interface Specifications

### 4.1 Structure and Organization Overview

See section 3.1.3 for general overview. Note that different processing levels are stored as different DATA\_SETs.

Now as defined in section 3.1.3 we have the following structure for each year in the DATA directory.



### 4.2 Data Sets, Definition and Content

Two levels of data are used: Raw (edited) data and calibrated data. The raw edited data contains the raw counts from the detector, sorted into the PDS format and with UT calculated and a quality parameter set to indicate data quality.

For the calibrated data a background subtraction has been performed and the calibration tables to turn counts into physical flux units.

The raw data archive also contains the housekeeping data from the TM stream in uncalibrated format.

### 4.3 Data Product Design

ICA produce two kinds of data, ion mass energy spectrograms and housekeeping data (HK). The instrument can be run in different modes, resulting in different resolution, but the data format is the same.

A complete set of edited data consists of housekeeping and science data. Calibration files in the CALIB



directory will also be needed to interpret the data.

A complete set of calibrated data consists of science data only.

#### 4.3.1 Data Product "Uncalibrated data" Design

The labels below follow the RPC and PDS conventions. ICA specific options are the mode ID which describes the ICA mode of operation. This is not necessary for the end user to know, as the resulting resolution of the data is anyway evident from the data. The instrument modes are described in the ICMA\_TCTM.PDF document in the DOCUMENTS directory. They are:

ID	Name
MSPO	Minimum spectra only
MSIS	Minimum, selected ion species
MEXM	Minimum, energy mass matrix
NRM	Normal mode, intermediate resolution
HAR	High angular resolution
EXM	High mass resolution
TEST	Test mode
CAL	Calibration mode
FAKE	Test mode producing artificial data stream

The data files consist of 106 columns. These columns are described in words below and later a sample label file is shown. The number of rows is variable. In the sample below figures from a real file is provided.

#### Column

1. Start time of the observations in Universal Time
2. Bad HV mask, a status bit which describes if the bad HV mask was enabled (see section 2.4.4)
3. Shadow mask, a status bit which describes if the shadow mask was enabled (see section 2.4.4). If enabled all azimuth and elevation angle combinations shadowed by the spacecraft are set to zero. If not, the counts need not be exactly zero and may be used to estimate background levels, at the expense of using more telemetry.
4. PROM section, ICA can run from different PROM software banks. Usually not important for the end user.
5. Post-acceleration reference level (0-7). Necessary to know in order to interpret the mass channels correctly in terms of physical mass of measured particles. Which mass table to use for a certain post-acceleration reference value is given in the file "ICA\_POST\_ACC\_TABLE\_V02.LBL" in the CALIB directory.
6. Mass table used. ICA may use mass look-up tables on board to bin data into certain physical mass ranges (see section 2.4.3). This column describes which of three on-board tables was used. 0 indicates that no mass look-up table was used, 1 indicates the table for no post-acceleration, 2 low post acceleration and 3 high post-acceleration.
7. Azimuth index describing the start sector of the sectors binned together to produce the data (see sections 2, 2.4.3 and figures 2 and 3)
8. Azimuth index describing the last sector of the sectors binned together to produce the data.
9. Mass channel number describing the start mass channel of those binned together to produce the data. See sections 2 and 2.4.3.
10. Mass channel number describing the end mass channel of those binned together to produce the



- data.
11. Elevation index describing the start elevation angle index of the elevation angles binned together to produce the data (see sections 2, 2.4.3 and figures 2 and 3)
  12. Elevation index describing the end elevation angle index of the elevation angles binned together to produce the data
  13. – 107 contains 96 count-values for the 96 different energy steps in the energy spectrogram. The counts are the sum over all sectors, elevation angles and mass channels used to produce the data according to the previous columns. The energy levels are found in the file ICA\_ENERGY\_TABLE\_V02.LBL in the CALIB directory.

Example of edited raw data detached label file (e.g. RPCICAYMMDDTHH\_000\_96L2.LBL)

```
PDS_VERSION_ID = PDS3
LABEL_REVISION_NOTE = "V0.83"
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 633
FILE_RECORDS = 43008
FILE_NAME = "RPCICA141228T01_000_96L2.LBL"
^TABLE = "RPCICA141228T01_000_96L2.TAB"
PRODUCT_ID = "RPCICA141228T01_000_96L2"
DATA_SET_ID = "RO-C-RPCICA-2-ESC1-RAW-V1.0"
DATA_SET_NAME = "ROSETTA-ORBITER 67P RPCICA 2 ESC1 UNCALIBRATED V1.0"
PROCESSING_LEVEL_ID = "2"
PRODUCT_TYPE = "EDR"
PRODUCT_CREATION_TIME = 2016-11-10T09:34:23
MISSION_ID = "ROSETTA"
MISSION_NAME = "INTERNATIONAL ROSETTA MISSION"
INSTRUMENT_HOST_ID = "RO"
INSTRUMENT_HOST_NAME = "ROSETTA-ORBITER"
INSTRUMENT_MODE_ID = "EXM"
INSTRUMENT_MODE_DESC = "HIGH MASS RESOLUTION"
```

```
TARGET_NAME = "67P/CHURYUMOV-GERASIMENKO 1 (1969 R1)"
TARGET_TYPE = "COMET"
MISSION_PHASE_NAME = "COMET ESCORT 1"
START_TIME = 2014-12-28T01:02:27.731
STOP_TIME = 2014-12-28T01:53:27.763
SPACECRAFT_CLOCK_START_COUNT = "1/0378349275.18432"
SPACECRAFT_CLOCK_STOP_COUNT = "1/0378352335.20476"
SC_SUN_POSITION_VECTOR = (-261258543.9830091,
    299238679.8677010, 48452507.9838860)
SC_TARGET_POSITION_VECTOR = ( 16.3387117, 11.2983001,
    19.5370065)
SC_TARGET_VELOCITY_VECTOR = ( -0.0000651, -0.0000848,
    0.0001097)
SPACECRAFT_ALTITUDE = 27.86215547
SUB_SPACECRAFT_LATITUDE = -68.46921725
SUB_SPACECRAFT_LONGITUDE = -65.53321395
```

NOTE = "  
The values of the keywords SC\_SUN\_POSITION\_VECTOR,



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SC\_TARGET\_POSITION\_VECTOR, SC\_TARGET\_VELOCITY\_VECTOR  
are related to the equatorial J2000 inertial frame.

The values of SUB\_SPACECRAFT\_LATITUDE and  
SUB\_SPACECRAFT\_LONGITUDE refer to the Cheops reference  
frame.

The SPACECRAFT\_ALTITUDE gives the distance to the spacecraft  
from the target center of mass.

All values are computed for the time t=START\_TIME. Distances  
are given in <km>, velocities in <km/s>, and angles in <deg>.

LBL & TAB FILES HAVE BEEN GENERATED BY S/W: pdsica.py VERSION 0.03  
TIMECORR FILE USED. SPICE USED."

PRODUCER\_ID = "RPC\_ICA\_KIRUNA\_TEAM"  
PRODUCER\_FULL\_NAME = "NILSSON, HANS"  
PRODUCER\_INSTITUTION\_NAME = "SWEDISH INSTITUTE OF SPACE PHYSICS KIRUNA"  
INSTRUMENT\_ID = "RPCICA"  
INSTRUMENT\_NAME = "ROSETTA PLASMA CONSORTIUM - ION COMPOSITION ANALYSER"  
INSTRUMENT\_TYPE = "PLASMA INSTRUMENT"  
DATA\_QUALITY\_ID = "01"  
DATA\_QUALITY\_DESC = "  
-1:INVALID. 0:SERIOUSLY AFFECTED BY HIGH BACKGROUND LEVELS. 1:NOMINAL.  
2:BACKGROUND SUBTRACTED."

ROSETTA:ICA\_ENERGY\_TABLE\_NAME = "ICA\_ENERGY\_TABLE\_V04.LBL"  
ROSETTA:ICA\_ENERGY\_TABLE\_DESC = "  
THE TABLE DESCRIBES THE ENERGY LEVEL CORRESPONDING TO EACH OF THE 96 COLUMNS  
GIVING COUNTS PER ENERGY LEVEL. THE TABLE IS FOUND IN THE CALIB DIRECTORY."  
ROSETTA:ICA\_MASS\_TABLE1\_NAME = "ICA\_MASS\_LOOKUP\_TABLE1\_V04.LBL"  
ROSETTA:ICA\_MASS\_TABLE2\_NAME = "ICA\_MASS\_LOOKUP\_TABLE2\_V04.LBL"  
ROSETTA:ICA\_MASS\_TABLE3\_NAME = "ICA\_MASS\_LOOKUP\_TABLE3\_V04.LBL"  
ROSETTA:ICA\_MASS\_TABLE\_DESC = "  
WHEN THE MASS CHANNEL RESOLUTION IN THE TELEMETRY IS REDUCED BELOW 8 THE  
MASS CHANNELS ARE BINNED TOGETHER IN CERTAIN MASS CHANNEL RANGES EXPECTED TO  
CORRESPOND TO CERTAIN ION MASS RANGES. THESE WILL VARY FOR DIFFERENT POST-  
ACCELERATION SETTINGS AND ENERGY AND THUS 3 DIFFERENT TABLES ARE PROVIDED  
FOR DIFFERENT POST-ACCELERATION SETTING. THE BINNING IS DESCRIBED IN THE  
TABLES DESCRIBED BY THE MASS\_TABLE\_NAME KEYWORDS. THE TABLES ARE FOUND IN  
THE CALIB DIRECTORY. WHICH TABLE WAS USED IS GIVEN BY A COLUMN IN THE DATA."  
ROSETTA:ICA\_ELEVATION\_TABLE\_NAME = "ICA\_ELEVATION\_TABLE\_V04.LBL"  
ROSETTA:ICA\_ELEVATION\_TABLE\_DESC = "  
THE NOMINAL ANGLES FOR EACH ELEVATION INDEX ARE NOT REACHED FOR ALL  
ENERGIES. THE ELEVATION TABLE GIVES THE ACTUAL ELEVATION ANGLES FOR EACH  
ENERGY."

OBJECT = TABLE  
NAME = "RPCICA-2-ESC1-RAW"  
INTERCHANGE\_FORMAT = ASCII  
ROWS = 43008  
COLUMNS = 13  
ROW\_BYTES = 633  
DESCRIPTION = "DETECTOR COUNTS PER TIME, SECTOR (AZIMUTH ANGLE),  
ELEVATION ANGLE AND MASS BIN. THE SIZE OF THE AZIMUTH ANGLE, ELEVATION



ANGLE AND MASS BINS ARE GIVEN AS THESE MAY VARY CONTINUOUSLY."

OBJECT = COLUMN  
NAME = TIME.UTC  
DATA\_TYPE = TIME  
START\_BYTE = 1  
BYTES = 26  
FORMAT = "A26"  
UNIT = "N/A"  
DESCRIPTION = "TIME OF OBSERVATION YYYY-MM-DDTHH:MM:SS.sssss"  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = BAD\_HV\_MASK  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 28  
BYTES = 1  
FORMAT = "I1"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 1  
UNIT = "N/A"  
DESCRIPTION = "INDICATES WHETHER BAD-HV MASK WAS ON OR OFF. IF ON ENERGY-ELEVATION ANGLE COMBINATIONS WHICH COULD NOT REACH THE NOMINAL VALUE OF ELEVATION ANGLE ARE SET TO ZERO. FOR LOW ENERGIES LIMITED RESOLUTION OF THE ELEVATION DEFLECTION VOLTAGE IS LIMITING, FOR HIGH ENERGIES INSUFFICIENT HIGH VOLTAGE IS LIMITING."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = SHADOW\_MASK  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 30  
BYTES = 1  
FORMAT = "I1"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 1  
UNIT = "N/A"  
DESCRIPTION = "INDICATES WHETHER SHADOW MASK WAS ON OR OFF. IF ON IONS COMING FROM ANGLES BLOCKED BY THE SPACECRAFT ARE SET TO ZERO. IF OFF THE CORRESPONDING SECTORS WILL LIKELY PRODUCE VERY FEW COUNTS ANYWAY, BUT MAY BE USEFUL FOR BACKGROUND SUBTRACTION."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = PROM\_SECTION  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 32  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 1  
VALID\_MAXIMUM = 16  
UNIT = "N/A"



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DESCRIPTION = "ICA CAN RUN USING SOFTWARE AND TABLES FROM DIFFERENT PROM SECTIONS. THE NUMBER OF THE PROM SECTION USED IS PROVIDED IN THE SCIENCE PACKET HEADER AND IS RETAINED HERE TO MAKE THE DATA COMPLETE."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = PACC\_LEVEL\_REFERENCE  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 35  
BYTES = 1  
FORMAT = "I1"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 7  
UNIT = "N/A"  
DESCRIPTION = "REFERENCE VALUE DESCRIBING THE POST-ACCELERATION LEVEL. THE LEVEL OF THE POST-ACCELERATION MUST BE KNOWN AS IT AFFECTS BOTH THE DETECTOR EFFICIENCY AND WHERE A CERTAIN MASS WILL HIT THE DETECTOR SURFACE. DETAILS ARE FOUND IN ICA\_CAL.PDF IN THE DOCUMENTS DIRECTORY."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = MASS\_TABLE  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 37  
BYTES = 1  
FORMAT = "I1"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 3  
DESCRIPTION = "ICA HAS THREE ON-BOARD MASS-LOOK UP TABLES, FOR DIFFERENT RANGES OF THE POST-ACCELERATION SETTING. THE TABLES ARE ENERGY DEPENDENT AND THE CURRENTLY USED TABLES ARE FOUND IN FILES DEFINED BY THE KEYWORD ROSETTA: ICA\_MASS\_TABLE\_NAME. THE TABLES ARE FOUND IN THE CALIB DIRECTORY. TABLE 0 MEANS THAT NO ON-BOARD TABLE WAS USED AND THAT INDICATED MASS INDICES CORRESPOND TO PHYSICAL MASS CHANNELS ON THE MICRO CHANNEL PLATE. FOR TABLE 1, 2 AND 3 START AND STOP ARE THE SAME AND CORRESPONDS TO THE ION MASS GIVEN BY THE CORRESPONDING COLUMN OF THE MASS LOOKUP TABLE."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = AZIMUTHAL\_INDEX\_START  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 39  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 15  
UNIT = "N/A"  
DESCRIPTION = "START SECTOR (CORRESPONDS TO AZIMUTHAL ANGLE). THE DATA IN THIS ROW IS A SUM OF THE COUNTS FROM THE START TO THE STOP SECTORS (INCLUSIVE) GIVES INFORMATION ABOUT ANGLE OF INCIDENCE OF DETECTED PARTICLES. EACH SECTOR CORRESPONDS TO 22.5 DEGREES AND THE PHYSICAL LOCATION ON SPACECRAFT IS GIVEN BY SECTORS.PDF AND ICALOCATION.JPG IN THE GEOMETRY



DIRECTORY."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = AZIMUTHAL\_INDEX\_STOP  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 42  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 15  
UNIT = "N/A"  
DESCRIPTION = "STOP SECTOR (CORRESPONDS TO AZIMUTHAL ANGLE). THE DATA IN THIS ROW IS A SUM OF THE COUNTS FROM THE START TO THE STOP SECTORS (INCLUSIVE) GIVES INFORMATION ABOUT ANGLE OF INCIDENCE OF DETECTED PARTICLES. EACH SECTOR CORRESPONDS TO 22.5 DEGREES AND THE PHYSICAL LOCATION ON SPACECRAFT IS GIVEN BY SECTORS.PDF AND ICALOCATION.JPG IN THE GEOMETRY DIRECTORY."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = MASS\_CHANNEL\_START  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 45  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 31  
UNIT = "N/A"  
DESCRIPTION = "START MASS CHANNEL. THIS CORRESPONDS TO MASS CHANNELS ON THE MICRO CHANNEL PLATE IF MASS\_TABLE IS 0. FOR MASS\_TABLE = 1,2,3 THE START AND STOP MASS CHANNELS ARE THE SAME AND CORRESPONDS TO THE ION MASS RANGE DEFINED IN THE MASS LOOK UP TABLE. NOTE THAT THIS IS ENERGY DEPENDENT. THE MASS RANGE CORRESPONDS TO A RANGE OF MASS CHANNELS OF THE DETECTOR AND THE ACTUAL MASS MUST BE FOUND FROM CALIBRATION TABLES. THE ORIGINAL CALIBRATION RESULTS ARE FOUND IN ICA\_CAL.PDF IN THE DOCUMENTS DIRECTORY. CURRENTLY VALID LOOKUP MASS TABLES ARE GIVEN BY KEYWORDS ROSETTA:ICA\_MASS\_LOOKUP\_TABLEN\_NAME WHERE THE N AFTER TABLE IS 1, 2 OR 3."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = MASS\_CHANNEL\_STOP  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 48  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 31  
UNIT = "N/A"  
DESCRIPTION = "STOP MASS CHANNEL. THIS CORRESPONDS TO MASS CHANNELS ON THE MICRO CHANNEL PLATE IF MASS\_TABLE IS 0. FOR MASS\_TABLE = 1,2,3 THE START AND STOP MASS CHANNELS ARE THE SAME AND CORRESPONDS TO THE ION MASS RANGE





DEFINED IN THE MASS LOOK UP TABLE. NOTE THAT THIS IS ENERGY DEPENDENT.  
THE MASS RANGE CORRESPONDS TO A RANGE OF MASS CHANNELS OF THE DETECTOR AND  
THE ACTUAL MASS MUST BE FOUND FROM CALIBRATION TABLES. THE ORIGINAL  
CALIBRATION RESULTS ARE FOUND IN ICA\_CAL.PDF IN THE DOCUMENTS DIRECTORY.  
CURRENTLY VALID LOOKUP MASS TABLES ARE GIVEN BY KEYWORDS  
ROSETTA:ICA\_MASS\_LOOKUP\_TABLEN\_NAME WHERE THE N AFTER TABLE IS 1, 2 OR 3."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = ELEVATION\_INDEX\_START  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 51  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 15  
UNIT = "N/A"  
DESCRIPTION = "START ELEVATION ANGLE INDEX. THE DATA IN THIS ROW IS A SUM  
OF THE COUNTS FROM START ELEVATION ANGLE INDEX TO STOP ELEVATION ANGLE INDEX  
(INCLUSIVE) GIVES INFORMATION ABOUT ANGLE OF INCIDENCE OF DETECTED  
PARTICLES. THE DEFINITION OF THE ELEVATION ANGLE INDEX IS GIVEN IN FIGURE  
SECTORS.PDF IN THE GEOMETRY DIRECTORY. THE ANGULAR RESOLUTION IS GIVEN IN  
ICA\_CAL.PDF IN THE DOCUMENTS DIRECTORY."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = ELEVATION\_INDEX\_STOP  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 54  
BYTES = 2  
FORMAT = "I2"  
VALID\_MINIMUM = 0  
VALID\_MAXIMUM = 15  
UNIT = "N/A"  
DESCRIPTION = "STOP ELEVATION ANGLE INDEX. THE DATA IN THIS ROW IS A SUM OF  
THE COUNTS FROM START ELEVATION ANGLE INDEX TO STOP ELEVATION ANGLE INDEX  
(INCLUSIVE) GIVES INFORMATION ABOUT ANGLE OF INCIDENCE OF DETECTED  
PARTICLES. THE DEFINITION OF THE ELEVATION ANGLE INDEX IS GIVEN IN FIGURE  
SECTORS.PDF IN THE GEOMETRY DIRECTORY. THE ANGULAR RESOLUTION IS GIVEN IN  
ICA\_CAL.PDF IN THE DOCUMENTS DIRECTORY."  
END\_OBJECT = COLUMN

OBJECT = COLUMN  
NAME = NO\_OF\_COUNTS  
DATA\_TYPE = ASCII\_INTEGER  
START\_BYTE = 57  
BYTES = 575  
FORMAT = "96(15)"  
ITEMS = 96  
ITEM\_BYTES = 5  
ITEM\_OFFSET = 6  
UNIT = "N/A"



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DESCRIPTION = "NO OF COUNTS OBTAINED FOR EACH ENERGY LEVEL, AND SPECIFIED  
SECTORS, DEFLECTION ANGLES AND MASS CHANNELS AS INDICATED.  
THE ENERGY STEPS ARE GIVEN IN SEPARATE FILE DEFINED BY KEYWORD  
ROSETTA:ICA\_ENERGY\_TABLE\_NAME."  
END\_OBJECT = COLUMN

END\_OBJECT = TABLE

END



#### 4.3.1.1 File Characteristics Data Elements

The \*.LBL file will be identified by the FILE\_NAME.

#### 4.3.1.2 Data Object Pointers Identification Data Elements

The only pointer used is from the \*.LBL file to the \*.TAB file. Keywords are also used to identify the correct calibration table from the CALIB directory to use for the data.

#### 4.3.1.3 Instrument and Detector Descriptive Data Elements

INSTRUMENT\_MODE\_ID describes the instrument mode. The instrument mode determines the data resolution but this is evident from the data and not strictly necessary for the end user to know. The instrument modes are:

The instrument modes are described in the ICMA\_TCTM.PDF document in the DOCUMENTS directory. They are:

ID	Name
MSPO	Minimum spectra only
MSIS	Minimum, selected ion species
MEXM	Minimum, energy mass matrix
NRM	Normal mode, intermediate resolution
HAR	High angular resolution
EXM	High mass resolution

ROSETTA:ICA\_ENERGY\_TABLE\_NAME Describes the energy table currently in use. ROSETTA:ICA\_MASS\_TABLE1\_NAME ,ROSETTA:ICA\_MASS\_TABLE2\_NAME, ROSETTA:ICA\_MASS\_TABLE3\_NAME gives the names of the currently used mass lookup tables. These tables relates which ion mass corresponds to which range of detector mass channels for a given energy and post acceleration setting. The three different tables are used for three different ranges of post-acceleration settings, corresponding to post-acceleration reference levels as:

Number of table	Post acceleration reference value
1	0
2	1-4
3	5-7

ROSETTA:ICA\_ELEVATION\_TABLE\_NAME gives the elevation table currently in use. This provides more precise elevation angles for particles of different energies than the nominal angles described in section 2 and shown in figure 2.

#### 4.3.1.4 Structure Definition of Instrument Parameter Objects

N/A

#### 4.3.1.5 Data Object Definition

All data stored in \*.TAB files. Their structure is defined by OBJECT Table definition within \*.LBL file. Each data definition block has a DESCRIPTION which explains the meaning of the



assigned data columns.

#### 4.3.1.6 Description of Instrument

The basics of the instrument is described in section 2 of this document.

#### 4.3.1.7 Parameters Index File Definition

N/A

#### 4.3.1.8 Mission Specific Keywords

None.

### 4.3.2 Data Product "Calibrated data" Design

Will contain background subtracted data in physical units (particle flux). Possibly the azimuth and elevation indices will be replaced by real angles (degrees/radians) or some other vectors in the spacecraft coordinate system. Another possibility is to retain the index system, as the tables for their interpretation are easily available in the CALIB directory. Then the format will be identical to RAW except that we may remove auxiliary information such as prom-section used, and the data values are changed from counts to flux.

## 5 Appendix: Available Software to read PDS files

A sample MATLAB script is provided, named READICA2.M. The file reading follows C syntax so it can easily be ported to C, and contains the information needed to quickly write a Fortran read routine.

## 6 Appendix: Example of Directory Listing of Data Set X

```
|-- AAREADME.TXT
|-- BROWSE
|  |-- 2006
|  |  |-- FEB
|  |  |  |-- D24
|  |  |  |-- RPCICA060224.LBL
|  |  |  |-- RPCICA060224.PNG
|  |  |  |-- RPCICA060224T05.LBL
|  |  |  |-- RPCICA060224T05.PNG
|  |  |  |-- RPCICA060224T06.LBL
|  |  |  |-- RPCICA060224T06.PNG
|  |  :  :
|  |  :  :
|  |  :  :
|  |-- BROWINFO.TXT
|  |-- BROWSE.HTM
|  |-- BROWSE.LBL
```



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```
-- CALIB
|-- CALINFO.TXT
|-- ELEVATION
| |-- ELEVATIONINFO.TXT
| |-- ICA_ELEVATION_TABLE_V02.LBL
| |-- ICA_ELEVATION_TABLE_V02.TAB
| |-- ICA_ELEVATION_TABLE_V03.LBL
| |-- ICA_ELEVATION_TABLE_V03.TAB
| :
|-- ENERGY
| |-- ENERGYINFO.TXT
| |-- ICA_ENERGY_TABLE_V02.LBL
| |-- ICA_ENERGY_TABLE_V02.TAB
| |-- ICA_ENERGY_TABLE_V03.LBL
| |-- ICA_ENERGY_TABLE_V03.TAB
| :
|-- MASS_LOOKUP
| |-- MASS_LOOKUPINFO.TXT
| |-- ICA_MASS_LOOKUP_TABLE1_V02.LBL
| |-- ICA_MASS_LOOKUP_TABLE1_V02.TAB
| |-- ICA_MASS_LOOKUP_TABLE2_V02.LBL
| |-- ICA_MASS_LOOKUP_TABLE2_V02.TAB
| |-- ICA_MASS_LOOKUP_TABLE3_V02.LBL
| |-- ICA_MASS_LOOKUP_TABLE3_V02.TAB
| |-- ICA_MASS_LOOKUP_TABLE1_V03.LBL
| |-- ICA_MASS_LOOKUP_TABLE1_V03.TAB
| :
|-- CATALOG
|-- CATINFO.TXT
|-- DATASET.CAT
|-- INST.CAT
|-- INSTHOST.CAT
|-- MISSION.CAT
|-- PERSON.CAT
|-- REF.CAT
|-- SOFTWARE.CAT

-- DATA
|-- EDITED
|-- 2006
|-- FEB
| |-- D24
| |-- RPCICA060224T05_000_96L2.LBL
| |-- RPCICA060224T05_000_96L2.TAB
| |-- RPCICA060224T05_000_GEOM.LBL
| |-- RPCICA060224T05_000_GEOM.TAB
| |-- RPCICA060224T05_000_HK.LBL
| |-- RPCICA060224T05_000_HK.TAB
```



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```
:      : :  
:      :  
:      :  
:      :  
|-- DOCUMENT  
| |-- DOCINFO.TXT  
| |-- ICATABLES.LBL  
| |-- ICATABLES.PDF  
| |-- ICA_CAL.LBL  
| |-- ICA_CAL.PDF  
| |-- ICA_CMD_BRIEF.LBL  
| |-- ICA_CMD_BRIEF.PDF  
| |-- ICA_EAICD  
| | |-- ICA_EAICD.LBL  
| | |-- ICA_EAICD.PDF  
| | |-- ICA_EAICD004.PNG  
| | |-- ICA_EAICD006.PNG  
| | |-- ICA_EAICD008.PNG  
| | |-- ICA_EAICD010.PNG  
| | `-- ICA_EAICD013.PNG  
| |-- ICMA_TCTM.LBL  
| |-- ICMA_TCTM.PDF  
| `-- SOFTWARE  
| | |-- GET_SW_VERSION.LBL  
| | |-- GET_SW_VERSION.M  
| | |-- ICAINITIALIZE.LBL  
| | |-- ICAINITIALIZE.M  
| | |-- IMPORT_L2.LBL  
| | |-- IMPORT_L2.M  
| | |-- PLOT_ICA.LBL  
| | |-- PLOT_ICA.M  
| | |-- READICA2.LBL  
| | |-- READICA2.M  
| | `-- SOFTINFO.TXT  
|-- GEOMETRY  
| |-- GEOMINFO.TXT  
| |-- ICALOCATION.JPG  
| |-- ICALOCATION.LBL  
| |-- ICA_FOV.JPG  
| |-- ICA_FOV.LBL  
| |-- SECTORS.LBL  
| `-- SECTORS.PDF  
|-- INDEX  
| |-- BROWSE_INDEX.LBL  
| |-- BROWSE_INDEX.TAB  
| |-- INDEX.LBL  
| |-- INDEX.TAB  
| `-- INDXINFO.TXT  
|-- VOLDESC.CAT
```



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